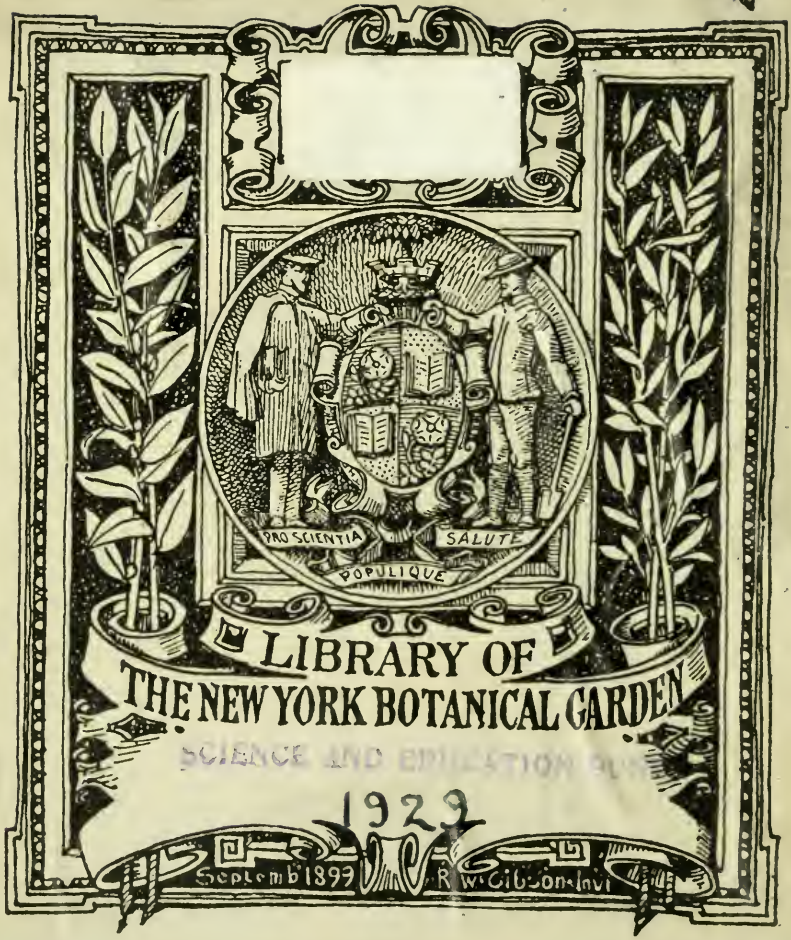

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CRYPTOGAMIC BOTANY.

A MANUAL

OF

CRYPTOGAMIC BOTANY,

ADAPTED TO THE REQUIREMENTS OF THE SCIENCE

AND ART DEPARTMENT.

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GARDEN

BY

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LONDON :

Published by the Author, 1, Banbury Street, Battersea.

1894.

GR505
.R65

Ashfield & Young,
printers,
Bridge Road West, Battersea.

PREFACE.

This work has been chiefly drawn up from my notes of Lectures delivered at Stockwell Training College, and the Public Library, Lavender Hill.

The material has been gathered from the most reliable sources, and frequent reference to Sachs' excellent Text Book, to De Bary's Comparative Morphology and Biology of the Fungi, and to the works of Strasburger, Bower, and Vines has been made.

The chief aim of the book has been to reduce to a concise form the life histories of the various plant organisms, detailed in the Advanced Syllabus of the Science and Art Department. The special difficulty of young students studying for this examination is a want of the necessary time to pick out from a host of others the special characters of the species intended for detailed study; this difficulty I have attempted to overcome, believing that when these types have been thoroughly mastered the larger works will be read with profit and pleasure. The book has been

interleaved with blank pages to encourage students *to draw, if possible, from the microscope*, the necessary diagrams for themselves, for a careful microscopic drawing is infinitely more valuable than a mere text-book description.

In conclusion, I must add that Dr. Scott's and Professor Farmer's admirable lectures delivered at the Royal School of Science have been of great value in drawing up this little work, and that much of the information so gained has been supplemented by personal observation.

C.M.W.R.

December, 1893.

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Class.—FUNGI.

Order 1.—Saccharomycetes.

Type.—YEAST (Torula) Saccharomyces Cerevisiæ.

Small round or ellipsoidal cells, having a diameter of about ·0003 of an inch. Each cell is an individual plant which lives an isolated life.

STRUCTURE.

A thin, smooth, cellulose wall encloses a cavity filled with protoplasm, and one or more vacuoles. According to Strasburger a nucleus is always present, but nuclear division has not yet been observed. The cell wall is very rarely coloured blue by iodine and sulphuric acid, and is considered a special modification under the name of fungus cellulose. Starch and chlorophyll are never present, the characteristic contents being a fatty oil. The protoplasm consists of proteids, the chief being "Protein," a compound analogous to Casein.

The chemical elements present in (1) Cellulose, are Carbon, Hydrogen, Oxygen; (2) Protoplasm, are Carbon, Hydrogen, Oxygen, Nitrogen and Sulphur.

The wall also contains minute quantities of Calcium, Potassium, and Magnesium.

When growing in a liquid capable of fermentation, the Torulæ multiply very rapidly by budding and abstriction. They require Oxygen for their growth, either free, or diffused through the liquid.

REPRODUCTION.

Budding and Abstriction.

Each cell gives rise to a minute protuberance (in some cases more than one) which grows rapidly; after having attained the size of the parent cell it is separated by a septum of cellulose. This cell becomes detached after having developed a second generation of buds. When the growth is energetic long chains are formed. When the growth is slow, abstriction takes place before the "bud" has attained its full size. Each cell can thus have an independent life, and repeat the process of budding. In rare cases the Saccharomyces multiply by spores or endogenous free cell formation. The protoplasm divides into four masses, each of which surrounds itself by a cell wall. These are set free by the dissolution of the mother cell. Each of these can repeat the same process. The necessary cellulose, protein, and oil are manufactured by the yeast plant out of the nutrient fluid.

DISTRIBUTION.

Saccharomyces are believed to be always present in the air, forming a sort of invisible dust. They

are cultivated in the process of brewing; they appear in nature on the surface of fruits, causing a fermentation of their juices after they (the fruits) have been crushed. They appear as moulds on the surface of fermented liquids, such as beer and wine, causing further decomposition. They are the cause of the disease known as Thrush.

Yeast cells growing in a saccharine solution cause fermentation to be set up. The sugar is decomposed into Carbon di-oxide and Alcohol. A minute quantity of glycerine and succinic acid are formed at the same time. The alcohol remains in the liquid, and carbon di-oxide is given off.

If the fluid be free from oxygen fermentation takes place, but the yeast cells do not grow, they pass into a dormant condition and finally perish. Dead yeast cells do not cause fermentation.

Order 2.—Zygomycetes.

Type.—MUCOR MUCEDO.

This is a common mould fungus which grows on living plants, decaying vegetable substances and the surface of organic solutions (glue or saccharine fluids). The fungus derives its nourishment from the material on which it grows.

DESCRIPTION OF A MATURE MUCOR.

The vegetative part—the *mycelium*—consists of copiously branched irregularly septate sacs, each of which contains streaming protoplasm and many nuclei. Each branch, whether septate or unseptate, is called a *hypha*.

From these hyphæ arise the straight, unseptate, unbranched, fruiting branches, called *Conidiophores* (or gonidiophores) which are also multinuclear, and in these the streaming of the protoplasm can be specially well observed.

Each filament or conidiophore bears a globular head—the *Sporangium*. The conidiophores are an inch or more in length, and turn towards the source of light. The sporangium is round, yellow or brown, the contents being yellowish-brown protoplasm, and

many nuclei. The conidiophore ends in the interior of the sporangium with a swelling like a ninepin. This swelling is called the *columella*. The wall of the sporangium is rough with minute particles of Calcium oxalate ($Ca\ C_2\ O_4$).

ASEXUAL REPRODUCTION.

The contents of the sporangium (protoplasm and nuclei) gradually separate into a number of masses, each of which secretes a cellulose wall (*free cell formation*). The cells thus produced are termed "spores"; these are the reproductive organs, and being produced asexually are known as *conidia* (gonidia). Each conidium on germinating gives birth to a new Mucor. The conidia while in the sporangium are separate from each other, the spaces between them being occupied by a thin protoplasmic material. The sporangium now dehisces, being easily ruptured, and the conidia are dispersed; the greater part of the sporangium wall disappears, but a small collar frequently adheres to the conidiophore.

Germination.—Each conidium is ellipsoidal in shape, has a thin fungus-cellulose coat which encloses a cavity containing protoplasm and one or two nuclei.

(1) The conidium *swells* to a tenfold size, becomes globular, and contains cell sap in the form of a large central vacuole.

(2) Several tubes are quickly developed, these grow rapidly and produce the *mycelium*. The successive systems diminish in size. In this stage the mycelium is unicellular ; nuclei, protoplasm and vacuoles abound. When it has covered an area of a few inches, growth ceases.

(3) The *protoplasm* becomes more granular and darker, and *collects towards the middle* of the mycelium.

(4) The *conidiophores are erected* out of the fluid as thick unicellular filaments ; while this is going on the mycelium developes septa.

(5) The conidiophore at its free end swells into a head, which is quickly supplied by the dense protoplasm from the mycelium, the protoplasm being replaced by cell sap.

(6) The wall of the *columella* is developed.

(7) The *conidia* are developed by free cell formation.

(8) The conidiophore rapidly elongates.

(9) *Dehiscence* takes place and the spores are dispersed, which in their turn germinate.

The time occupied from germination to maturity is about three days.

In *Pilobolus*, another of the Mucorini, the sporangium remains intact, but when ripe becomes detached

at its base, and together with the conidia is thrown some distance by its elasticity.

SEXUAL REPRODUCTION.

Mucor is also propagated sexually in the following way:—

(1) Two filaments of the mycelium each put out in the direction of the other a cylindrical protuberance resembling the filament itself.

(2) These two protuberances become closely adpressed to one another by their ends, and grow into a club-shaped body in which a quantity of protoplasm collects.

(3) Each of the club-shaped ends is cut off by a septum of cellulose, in this way the two conjugating cells are formed.

(4) The separating wall disappears, and the contents of both cells mingle, the result being the formation of a *Zygospore*, which is the reproductive organ.

(5) The zygospore rapidly rounds off and enlarges considerably: the two attached mycelial threads grow large and form *Suspensors*.

(6) The wall of the zygospore becomes considerably thickened; the outer portions become dark, cuticularised, and often spiny, the inner remaining a colorless layer of pure cellulose. The outer coat is called the *exospore* and the inner the *endospore*.

Germination of a Zygospore.—This takes place after a period of rest—about six weeks—the inner cellulose wall produces a single hypha, the outer cuticularised wall being ruptured to allow its exit. The hypha bears a sporangium which behaves in all ways exactly the same as that borne by the ordinary mycelium.

Order 3.—Ascomycetes.

Type.—EUROTIUM REPENS.

A fungus found on decaying or dead organic bodies, and especially abundant on preserved fruit. It makes its appearance as a delicate flocculent white mycelium overspreading the surface, from which the upright conidiophores soon rise in large numbers.

ASEXUAL REPRODUCTION.

The conidiophores swell in the upper part into a globular form, and on the upper half of the globe there arise a number of peg-shaped projections densely crowded and arranged radially, so that finally the head of the receptacle is covered by a thick layer of them. These are known as *Sterigmata*, each of which produces a long chain of greenish conidia by abstriction. This differs from the ordinary process of cell division only in the marked constriction of the cell in the plane of division. These conidia are sometimes called *Stylospores*. When ripe they drop off and germinate by putting out a filament from the endospore.

SEXUAL REPRODUCTION.

During the formation of conidia the sexual organs appear on the mycelium. The female organ, the

ascogonium, is a corkscrew-like end of a branch of the mycelium, the coils of which gradually become closer, and when actually in contact they form a hollow spiral. During this process there are as many septa formed as there are turns of the spiral.

From the lowest coil of the ascogonium two slender branches now shoot out at opposite points, and grow upwards on the outside of the spiral (*helix*) one of these develops more quickly than the other, reaches the uppermost coil, and becomes closely attached to it by its apex. This branch is the *pollinodium*.

Conjugation takes place between its apex and that of the ascogonium, the cell walls being absorbed at the point of contact, the protoplasmic contents of the two cells commingle. Soon afterwards new filaments sprout out from the lower part of the pollinodium and ascogonium, cling closely to the spiral and finally envelop it. From these filaments a layer of polygonal cells is formed by numerous transverse divisions.

The cells of the enveloping layer grow inwards as papillæ, which become septate.

The enveloping layer increases in size, the cavity between it and the ascogonium also enlarges, the coils of the ascogonium loosen. The whole space becomes filled up by the papillæ, which become

divided by septa, and so form a mass of pseudo-parenchyma.

A large number of septa arise in the ascogonium, and soon there shoot from its cells numerous branches, which penetrate on all sides between the cells of the pseudo-parenchyma, become septate and ramify. Their last ramifications are the *Asci*, which therefore owe their origin to the fertilized ascogonium. All this time the *perithecium*, (*i.e.*, the tissues developed as the result of fertilization) has been increasing in size.

During the development of the Asci, the pseudo-parenchyma becomes looser, its cells round themselves off, become capable of swelling, lose their fatty contents and disappear, their place being taken by the Asci.

The outside enveloping layer from which the pseudo-parenchyma is derived keeps pace in growth and becomes covered with a sulphur-yellow coating, which attains a considerable thickness and consists probably of a resinous or fatty substance.

Finally these cells also collapse and dry up; the eight-spored asci also break up, till finally the perithecium consists only of the brittle yellow coating and the mass of spores enclosed by it, which are set free by gentle pressure.

In a similar manner to the perithecium the mycelium also becomes covered by a coating, in this

case of a chestnut colour, on which the perithecia are now individually visible to the naked eye as yellow granules. The ripe spores have the form of bi-convex lenses; when germinating the endospore, which puts out the germinating filament, swells up violently and splits the exospore into two halves. The mycelium which proceeds from the Ascospores produces, like that which arises from the conidia, at first Conidiophores, and afterwards Perithecia.

Order 4.—Basidiomycetes.

Type.—MUSHROOM. AGARICUS CAMPESTRIS.

The common Mushroom consists of:—

(1) The mycelium.

(2) The fructifications.

(1) *The Mycelium* is composed of septated hyphæ, containing many small nuclei, and abundant protoplasm. It vegetates on decaying animal or vegetable matter. From the mycelium spring a number of fructifications.

(2) *Development of the Fructification.*—This consists at first of a solid, pear-shaped body composed of young hyphæ, all similar to one another.

At an early stage an annular air-cavity is left just beneath the apex, the upper wall of which becomes the under side of the *pileus*, and from this radial *hymenial lamellæ* grow down, filling up the cavities.

The tissue below the cavity elongates into a stalk, while the hyphæ forming the margins of the pileus constantly increase.

The hyphæ which lie beneath the air-cavity become stretched and separate from the stem from below upwards and so form a membrane. This runs from the upper part of the stalk to the margins of the pileus, into which their hyphæ are continued. As

the pileus goes on extending horizontally, this membrane becomes detached from the pileus, and hangs down from the stem like a ruffle. This is called the *Annulus*.

STRUCTURE OF THE STALK.

The hyphæ are arranged parallel to each other generally, but single ones run obliquely to the others. The parallel hyphæ are branched, each branch usually arising just under a septum. The external ones are narrow and close together. In the middle the arrangement is irregular, and air fills the interspaces. In the latest stages vacuoles and crystals of Calcium Oxalate appear. In cross section it will have a parenchymatous appearance. Pits are frequently seen in the cross walls, one usually occupying the middle.

REPRODUCTION.

The pileus bears on its underside a number of lamelliform projections. A section cut at right angles to the course of the lamellæ will exhibit a comb-like appearance. Highly magnified each tooth of the comb shows the following structure :—

(1) A number of septated hyphæ called the *Trama*. They diverge from the centre to the right, and form:—

(2) *The sub-hymenial layer*. From the sub-hymenial layer arise short, club-shaped hyphæ, densely crowded, and at right angles to the

surface of the lamellæ. These form :—

(3) *The Hymenium.* Many of these club-shaped sacs remain sterile. These are called *Paraphyses*, others produce the spores, and these are called *Basidia.*

Each basidium produces in this species only two, in other Basidiomycetes usually four spores.

The basidium puts out first of all as many slender branches as there are spores to be formed. These branches are the *Sterigmata.* Each sterigma swells at the end : the little swelling is cut off by a wall, and becomes a spore. In this species the spore remains smooth. When ripe it falls off from its sterigma. The spore is ellipsoidal in shape, and is known as a *Basidiospore.*

The wall of each spore is thick in proportion to its size, it contains abundant protoplasm, many small nuclei and vacuoles even before it is septated from the sterigma.

When germinating it produces several tubes, which give rise to the mycelium, this in its turn produces the pear-shaped solid masses of hyphæ which ultimately become the fruits. A development of sexual organs, by means of which the formation of the fruit could take place, has not yet been observed.

Class.—LICHENS.

Order.—Ascomycetes.

Type.—COLLEMA PULPOSUM.

"Lichens are true fungi belonging to the *Ascomycetes*; they are distinguished by a peculiar parasitism. *Their hosts are Algæ* which grow in damp places, but not actually in water. Lichens are not found in any other form but as parasites on Algæ. The Algæ when combined with the Fungus, are called *Gonidia*, and these Algæ are known in a free condition without the fungus. The gonidia of *Collema* has been identified with the alga *Nostoc*. The algæ grow as stains and incrustations on damp ground, the bark of trees, and stones. The separate cells and groups of cells become so involved by the tissue of the fungus that they at last are only interspersed here and there in the dense hyphal tissue of the fungus."

1. GENERAL CHARACTERS.

Collema grows on moist earth and rocks. Its *thallus* (the whole plant—so called because it shows no differentiation into root, stem, and leaf) may be all but ground to a powder without destroying its vitality. When saturated with water it becomes slimy

and gelatinous, and is therefore known as a *Gelatinous* Lichen. *Parmelia*, another lichen, becomes leathery when saturated with water, and this, therefore, is placed in the *non-gelatinous* class. *Collema* is again classed as a *Foliaceous Lichen*, because its thallus is green and leaf-like in appearance.

2. STRUCTURE.

In section *Collema* shows an *epidermis* or cortical rind, forming a sort of pseudo-parenchyma. This rind consists of a number of *septated hyphæ*, which do not differ in any particular from the hyphæ of the fungi already discussed. It is the cut ends of these elements which are seen in section. The interior consists of a *colorless jelly*, in which lie *chains of gonidia* and numerous *hyphæ*. The gonidia and hyphæ are about equally mingled, and the thallus is said to exhibit a *homoiomerous* structure.

(a) **Gonidia**. The wall of each cell is composed of normal cellulose, lying next to this is a band of protoplasm containing chlorophyll grains, and the centre is occupied by either a colorless or a blue vacuole. A nucleus is *always* present embedded in the protoplasm. These cells—gonidia—are arranged in bead-like rows. One or more cells in each chain is larger than its neighbours, and is colourless.

(b) The **Jelly** is now universally believed to be the outer gelatinous walls of the gonidia.

(c) The **Hyphæ** are elongated, greatly-interlaced, tube-like structures. Their walls are enormously thick when compared with the size of the cavities.

3. PHYSIOLOGY.

(a) **Respiration.** Oxygen is absorbed, and carbon di-oxide liberated as in the higher plants.

(b) **Assimilation.** The gonidia, as they contain chlorophyll, decompose Carbon di-oxide and water, and build up starch, at the same time liberating Oxygen. This can only go on in the presence of sunlight.

The hyphæ fit closely to the gonidia, and carry to them the crude sap which contains in solution Nitrate of Potassium, Sulphates of Calcium and Magnesium, and Chloride of Iron. These are all obtained from the soil or rock on which the lichen is flourishing. In return the hyphæ receive a share of the organic material elaborated by the gonidia. Gonidia and Hyphæ are thus closely associated and are dependent on each other; the gonidia receive from the hyhpæ the crude material, the hyphæ receive from the gonidia elaborated material. This mutual give and take is called Symbiosis, and is nowhere else exemplified in the vegetable kingdom.

4. MODE OF GROWTH.

The mode of growth, external structure, and

branching are all determined by the *gonidia*. The details are as follow :—

1. The branch increases at the apex by the transverse division of a gonidium which forms the apical cell of the branch and by the longitudinal growth of the hyphæ.
2. The cells produced from the apical gonidium divide parallel to the long axis of the branch.
3. New divisions take place in different directions, and thus groups of gonidia arise at some distance below the apex.
4. A few hyphæ follow the longitudinal growth and these grow within the gelatinous envelopes which are evidently derived from the gonidia.
5. At a considerable distance behind the apex new hyphæ put forth lateral branches which penetrate between the single or grouped gonidia, and this increases the branch in thickness.
6. When a lateral branch is about to be formed one of the exterior gonidia lengthens in a direction at right angles to the axis of the parent branch. This becomes the apical cell of the lateral branch, and produces new cells by transverse division.
7. Branches of the adjacent hyphæ turn in the same direction and behave in relation to the

new apical cell, in the same way as those of the parent branch.

8. The thallus increases in thickness by the branching of the hyphæ and the multiplication of the gonidia.

REPRODUCTION.

1. Sexual *(not universally accepted)*.

Flask-shaped depressions occur in the thallus called *Spermogonia*, in these are produced rod-like cells called *Spermatia*, by the process of abstriction. Each of these cells is regarded as a male reproductive organ.

The female organs are coiled hyphæ, which form spirals somewhere in the thallus, and then the ends run straight to the surface, and project slightly above. A single coiled hypha is an *ascogonium*. Many ascogonia occur in one thallus.

The male cells are brought by water, and come in contact with the straight part of the female organ. The walls between become disorganised and the contents of the male cell (*spermatium*) are conducted to the ascogonium. *Conjugation* is thus effected, and the result of this conjugation is the formation of special receptacles called *Apothecia*. *Note that the whole of the Sexual process is entirely concerned with the Hyphæ.*

3. Formation of the Lichen.

Before the dissemination of the spores some of the Gonidia crawl out of the parent plant and settle themselves at some little distance off. They produce the jelly and the large colorless cells, and so are ready to become the hosts of the fungus.

The spores falling in their neighbourhood germinate by putting out as a rule two filaments (hyphæ) from the endospore. They come in contact with the jelly of the gonidia and grow and ramify in all directions, until the little group of gonidial cells is entirely invested by their threads (hyphæ). A new lichen is thus formed; the young hyphæ take up the necessary food from the substratum, and convey it to the gonidia, which assimilate it; the gonidia use part of it for the growth and multiplication of their own cells, and give up the rest to the hyphæ. The thallus begins at once to produce the apothecia, which in their turn produce the spores; some of the gonidia wriggle out and away to form a new host for the germinating spores.

Facts in support of the Algo-Lichen theory above discussed.

1. If the green element be isolated from the fungus and cultivated, it gives a life history identical with some known alga. The alga of *Collema* is *Nostoc*.

2. While the gonidia are flourishing they never show even a tendency to produce the colorless hyphæ.
3. When the spores germinate and the hyphæ are not allowed to come in contact with an appropriate Alga they soon die and during their short span of life they remain colorless.

volume to the amount of CO_2 decomposed. This process is called *Assimilation*, and may be represented thus:— $6\ CO_2 + 5\ H_2O = C_6\ H_{10}\ O_5 + 6\ O_2$.

The Chlorophyll grains are larger than the ordinary grains of protoplasm, and as a rule lie next to the cell wall. The nucleus occupies the centre.

The changes to the active condition are as follows :—

(1) The protoplasm withdraws itself from the wall, except at two points.

(2) The protoplasm at these points protrudes through the wall as long threads.

(3) The cell wall becomes disorganised, and it now swims about as a naked cell, called a *Zoospore*, in which a red spot is clearly visible. This is known as the " Eye-spot."

Note.—One cell may produce as many as eight zoöspores, thus :

(1) The protoplasm splits into as many parts as there are zoöspores to be formed.

(2) Each mass develops two cilia, which protrude through the wall.

(3) The mother cell is disorganised, and the zoöspores are liberated.

Changes to the encysted condition.

(1) It loses its cilia.

(2) It clothes itself with a cell wall, and becomes quiescent.

REPRODUCTION.

Brought about by ordinary cell division : —

(1) The nucleus divides into two.

(2) A cell wall is developed in the plane of the division. Each of these cells can repeat the process.

(3) The daughter cells round themselves off. They may remain in union with each other for some time, but finally separate.

In all probability the *Protococcus* is only a form of some higher Alga.

Protococcus nivalis is "red snow"—resembles *P. pluvialis* in all respects except in its colouring matter.

P. Atlanticus, another species, imparts a red colour to the waters of the Atlantic in some places, and it is probably better to distinguish this as well as *P. nivalis* as *Hæmatococci*.

Order 2.—Zygnemaceæ.

Type.—SPIROGYRA NITIDA.

Spirogyra is a freshwater alga found particularly in ponds and springs, and may be recognised by its bright green or yellowish colour, as well as by the delicacy of its filaments. Each plant consists of a single, cylindrical, unbranched, thread of cells. Each cell wall is lined by a delicate, colorless, peripheral layer of protoplasm, which becomes clearly visible when the cell is treated with some water-withdrawing medium (solution of common salt or glycerine).

The *chlorophyll* takes the form of closely-wound *spiral bands* having a finely undulating outline, lying next to the protoplasm ; embedded in the band are the *amylum bodies*, sometimes known as *pyrenoids*. These are dense globular colourless grains, each of which contains a protein crystal, and is bounded by a hollow globe of small starch grains. A nucleus occupies the centre of each cell, and in some species exhibits the form of a bi-convex lens. In the centre lies a *nucleolus* ; sometimes as many as three nucleoli are present.

The nucleus is surrounded by a very thin layer of protoplasm, from which delicate protoplasmic threads

run out towards the peripheral protoplasm; these threads fork repeatedly and suspend the nucleus in the cell sap. The protoplasm also contains numerous drops of oil.

REPRODUCTION.

Two threads lie alongside of each other, the cells of each put out short blunt projections which come into contact, the absorption of the walls at the point of contact forms a narrow canal; since a number of cells usually *conjugate* at the same time, the whole forms a ladder-like structure, in which the rungs are represented by the canals.

After the formation of the conjugating canal the contents of the male cell round themselves off and withdraw entirely from the wall. They then pass into the canal and enter the female cell, which has rounded off (or is in the act of rounding off) its contents, both masses come into contact, and after a few minutes coalesce, *i.e.*, the protoplasm fuses, the chlorophyll bands join together, and the two nuclei unite into a single one. The result of this fusion is the formation of a globular or ovoid body, which first contracts and then acquires a thick cell wall. The whole still lies within the much larger mother cell. After a lapse of about twenty-four hours the chlorophyll band is pressed outwards, and the nucleus assumes a central position.

GERMINATION.

This takes place after a period of rest, so this *zygospore* is termed a resting spore.

Usually in the spring following its formation it escapes from the parent cell by the decay of the mother filament, or it may germinate while still within it. The innermost layer of the cell wall bursts through the outer ones, and develops into a filament like the parent plant.

Order 3.—Fucaceæ.

Type.—COMMON BLADDER WRACK. FUCUS VESICULOSUS.

This Alga may be olive-green or brownish in colour; it is flat, leaf-like, cartilaginous in texture, traversed by a midrib which projects on both sides, and bears bladder-like swellings in pairs (one on either side of the midrib) as well as singly at the base of the bifurcations; it is attached to stones by a branched attachment disc. The whole plant is called a *Thallus* because there is no differentiation into root, stem, and leaf. The branches of the Thallus are all in one plane, and as a rule the branching is *dichotomous*, *i.e.*, the apex ceases to grow in the original direction, and its continuation is in two new directions; the two newly-formed branches are termed *bifurcations*, and the member which produces them the *base* of the bifurcation. Every base can only bifurcate once, but every branch may become the base of a new bifurcation. Dichotomous branching is common to all the Algæ, but in some Fucaceæ the branching is *sympodial*. This is the case when one branch develops more strongly than the other, and the weak one then appears to be laterally developed; the bases of the successive bifurcations

appear to constitute an axis (which is called a *pseud-axis* or *sympodium*) on which the weaker branches appear as lateral branches, the successive bifurcations are alternately right and left, and so form a *scorpioid dichotomy*. The growth is brought about by a group of cells at the apex, called *primary meristem*, this lies in a depression, and is not differentiated. (In other cryptogams it is usually brought about by a single cell).

GENERAL ANATOMY.

The tissue consists at the surface of small cells, next to this it is laxer, and the midrib consists of thickened elongated cells.

The cell wall consists of two distinct layers, an inner thin firm one, and an outer gelatinous one (capable of swelling greatly in water) which fills up the interstices of the cells, and has the appearance of a structureless substance; this is the cause of the slimy character which the *Fucaceæ* assume after lying in fresh water. The granular contents appear to be mostly brown, but contain chlorophyll which is concealed by other colouring matters. The colour bodies are known as *Phæophyll* grains, and when treated with alcohol yield an olive-green extract; this extract when shaken up with double its volume of Benzine, and allowed to settle, produces an upper green layer containing the chlorophyll, while the lower alcoholic layer is yellow, and contains Phycoxantheine.

MINUTE STRUCTURE.

(1) **Epidermoid layer.** The cells are oblong in surface view, and rectangular in section; the cavities are closely filled with protoplasm and phæophyll grains.

(2) **The Cortex** is several cells in thickness and contains wide cavities filled with phæophyll grains, the cells are connected by pits—these are thin places in the cell-wall. *The innermost layer of the cortex is the thickening layer* (analogous with cambium in Phanerogams).

(3) **The Midrib** consists of elongated cells connected together into threads which run parallel to each other and to the long axis; the transverse walls are interrupted in a sieve-like manner, the threads are separated laterally by the jelly, which is bridged over by canals; the long walls are interrupted by broad pits.

(4) **The Wings.** The midrib is surrounded by a loose network of irregularly dispersed cells, and this passes over laterally into the *packing tissue* of the wings. This tissue is made up of irregular, thread-like cells similar to those of the midrib, it is poor in phæophyll grains, but is rich in oil globules. *A starch reaction is nowhere found.* The epidermoid and cortical tissues are assimilative, the packing tissue and midrib conductive.

(5) **The Bladders** are swellings which in a young state are filled with threads similar to those found

in the wings of the thallus ; scattered in the jelly belonging to these threads are bubbles of gas, which tear the loose tissue, and form the chambers of the bladders. Old bladders are hollow and filled with air and serve as swimming bladders, the outside walls are thick, being formed by successive divisions of the epidermoid layer.

(6) **The Stem.** The thallus in its oldest part is stem-like, and developed from the midrib, the wings of which have gradually died off. The innermost layer of the cortex (the thickening layer) begins its activity at an early stage ; at a little distance below the apex, tube-like prolongations are developed, which grow downwards into the jelly separating the threads ; these divide by cross-walls and branch from time to time, these thickening threads rarely pass into the wings. In cross-section the two kinds of elements can be distinguished :—

(i) Scattered cells with brownish contents (primary tissue.)

(ii) Numerous closely-packed cells with narrow cavities and greenish contents (secondary tissue).

While this has been going on the wings have died off, the outer layer of the midrib has become brown and dead and cast off, the second layer becomes

active, divides up by radial walls and soon closes round.

Fucaceæ yield *Acetic Acid* when fermented at a temperature of from 90 to 96 degrees Fahrenheit.

The epidermoid is in positive and the outer layer of the cortex in negative tension, that is, the outer layers are compressed by the inner layers, and the latter stretched by the outer.

REPRODUCTION.

The *Antheridia* (male) and *Oogonia* (female) are formed in spherical hollows—*conceptacles*—which make their appearance in large numbers at the ends of the branches. Each conceptacle communicates by a narrow channel—the *osteole*—with the sea water. The layer of cells which clothes the hollow is a continuation of the external epidermal layer of the Thallus and since the filaments which produce the Antheridia and Oogonia sprout from it, the latter are morphologically *trichomes* (any outgrowth from the epidermis, *e.g.*, hairs, is called a trichome.)

Some species are *monœcious*, *i.e.*, both kinds of sexual organs are developed in the same conceptacle, as in *Fucus platycarpus* (this species is further characterised by always being devoid of air-bladders); others are *diœcious*, *i.e.*, the conceptacles of one plant containing only oogonia, those of another only antheridia, as in *F. vesiculosus*. A number of hairs which grow in the conceptacles among the sexual

organs are long, slender, articulated, unbranched, and project in *F. platycarpus* out of the mouth of the conceptacle in the form of tufts—these help in the absorption of nutrient materials. Sterile conceptacles are often found—no doubt being produced to further aid in the absorption of nutrient matter from the sea water.

The Antheridia are produced as lateral ramifications of *branched* hairs. Each antheridium consists of a thin-walled oval cell, the contents of which go to form numerous small *antherozoids*; these are pointed at one end, and each is furnished with two unequal motile *cilia*; the short one is attached to the pointed or anterior end, and directed forwards; the longer one is attached laterally and directed backwards. The antherozoid consists of nuclear substance, and always shows one reddish-brown spot—due to the presence of one and *very* occasionally two colour bodies. It is at this spot that the lateral cilium is attached. The nuclear substance is surrounded by a thin layer of protoplasm—*Kinoplasm*. The whole of the contents of the antheridium is not used up, a little protoplasm is left.

The Oogonia. The formation of an oogonium begins with a papillose swelling of a parietal cell of the conceptacle; the papilla is separated off by a septum, and divides as it grows in length into two cells, a lower, the *pedicel* cell, and an upper, which forms the *oogonium*. This swells up into a spherical

or ellipsoidal form and becomes filled with dark fine-grained protoplasm; it contains a nucleus which by successive bi-partition becomes eight nuclei. The protoplasm separates into eight portions with a nucleus and a brown fleck in the middle of each (due to the aggregation of colour bodies). These completely fill up the cavity and pressing one against another, become polygonal. Each mass is an *oosphere* or female reproductive organ. (It is analogous with the ovum in higher plants).

The wall of the oogonium consists of two layers, the outer one splits, and the inner one protrudes in the form of a sac, which becomes distended by absorption of water; in this enlarged sac the oospheres become globular. The inner membrane now splits and the oospheres are liberated as naked balls of protoplasm, each of which has a central nucleus and its colour bodies equally diffused. At about the same time the Antherozoids are liberated by rupture of the antheridium, they swarm in large numbers round the oospheres, become attached to them by their anterior cilia—if their number is sufficiently great their movement is so energetic that they impart to the oospheres a rotatory motion which may last for half-an-hour. This phenomenon is nowhere else exhibited in the vegetable kingdom, though it is known in several genera in the animal kingdom. Some of the antherozoids mingle their substance with that of the oosphere, whose motion

ceases, and fertilization is effected. A short time after, a cell wall is secreted. This cell (*oospore*) fixes itself to some body, and without any period of rest begins to germinate. It forms first of all a transverse wall and begins to lengthen at the same time. Numerous other cell divisions follow and the mass of tissue thus formed puts out from the part on which it rests a root-like organ of attachment. The thick free end forms the growing apex.

Class.—MUSCINEÆ.

Sub-Class.—HEPATICÆ.

Order.—Marchantieæ.

Type.—A LIVERWORT.

MARCHANTIA POLYMORPHA.

GENERAL MORPHOLOGY.

Marchantia has a tough, leathery, thalloid stem, extended flat upon the ground, it is ribbon-like, dichotomously branched, and green. Along the centre of each shoot projects on the ventral (under) surface a midrib. The existence of simple, scale-like leaves can be detected with the aid of a microscope. There may be present three forms of scales :—

(1) Marginal scales which have become brown.

(2) Median scales, which lie in the middle line, and are usually purple.

(3) Laminar scales, which lie on either side of the middle line. The under side of the thallus also produces fine *rhizoids*, which are not true roots.

The upper surface of the thallus is interrupted by cup-like depressions called *Gemmæ cups*. With the aid of a lens the upper surface is seen to be divided into small, diamond-shaped areas. The limits of the areas are dark-green, the areas themselves being greyish. In the middle of each area is a dot-like opening surrounded by four narrow cells containing no chlorophyll and curved in the form of a crescent.

GENERAL ANATOMY.

In surface view the cells of the epidermis appear to be polygonal. The under surface shows no division into areas.

A cross-section of the thallus beginning at the dorsal (upper) surface, shows the following structure :—

1. Epidermis.

This is very distinctly differentiated, and is interrupted by large *stomata* of a peculiar form. The cells are generally oblong or polygonal, and contain numerous small chlorophyll grains.

The Stomata. Each stomata stands in the centre of a rhombic plate which overarches a large air-cavity, and which is formed by the upper cells becoming detached from those underneath. The stoma is formed by the simple separation from one another of four or more epidermal cells which afterwards

divide by walls parallel to the surface of the thallus. For this reason the opening is surrounded with from four to eight tiers of cells. The opening is narrowed at its upper and under surfaces, and therefore shows a barrel-shaped form.

2. Intercellular Spaces.

Under each stoma is found a large, intercellular space, into which project from below threads of cells (two or three cells long) occasionally branched. These cells are especially rich in chlorophyll, and they arise from the flattened cell layer next below which is poor in chlorophyll. The walls bounding the air-chamber laterally are constructed of loosely-combined cells, which also contain chlorophyll.

3. Cellular Tissue.

The tissue next under this consists of broader cells, which have reticulately thickened walls. They are almost free from chlorophyll and have no interstices.

4. Ventral Cortical Layer.

Approaching the ventral surface the last two layers are flat and narrow, and contain chlorophyll and form the so-called ventral cortical layer.

5. Epidermis.

The epidermis of the under surface is much

poorer in chlorophyll, and the cells are more elongated.

The Rhizoids, *i.e.*, Filaments which attach the plant to the substratum, and absorb water together with the necessary food material, proceed from the ventral surface, and are of two kinds.

(1) Thin-walled ones, with peg-like projections in the interior.

(2) Thick-walled ones without peg-like projections.

Those with the peg-like projections in their interior lie close to the frond, and follow the midrib in bundles and are covered by the scales. They serve perhaps the purpose of stiffening the thallus.

Those without the peg-like projections turn off from the thallus at once and enter the substratum. At their apex they are sinuately lobed, at their base purplish.

The Scales are the leaves which are simple plates one cell in thickness. The median cells are living, but the outer edges become brown and die off.

The projecting midrib consists of elongated thickened cells which contain no chlorophyll.

The Thallus grows by a group of apical cells.

Throughout the entire tissue are single cells, which are distinguished by a highly refractive, irregularly-outlined, grape-like body, which in the youngest shoots are slightly brownish, and in the older ones dark brown. These are *oil bodies*, which are characteristic of Liverworts.

In Marchantia are also found large cells with highly refractive contents, which on examination proves to be *mucilage*.

REPRODUCTION.

Vegetative. Multiplies by *gemmæ*, common among Liverworts—gemmæ arise on dorsal surface in broadly cup-shaped receptacles called *cupules*. The cups have a toothed rim, and at their bottom the bright green gemmæ are visible. From the bottom of the cup shoot out unicellular hair-like papillæ. Each divides first of all by a transverse wall; the lower cell of each papilla undergoes no further change, and is known as the *pedicel* cell. The upper one divides again by a transverse wall, and then longitudinally. Tangential division also takes place and in this way a great mass of tissue is formed, which is supported on a unicellular stalk. When mature it is the shape of a bi-convex lens, with two lateral indentations. At the bottom of the cup are also found club-shaped papillæ, the membrane of which swells into a mucus and causes the ejection of the gemmæ whose pedicel cells are broken through. The cells of the gemmæ are rich in chlorophyll, and the marginal ones contain oil bodies. Certain cells are also present which are large and devoid of chlorophyll. When the gemmæ have been pushed out of the cup, and lie exposed to light on damp ground, the two lateral depressions, which are the growing points, form the first flat shoots of the

thallus. The large cells not containing chlorophyll, on the side next the ground, develop in about thirty hours into the rhizoids. The side exposed to the light becomes the dorsal side.

SEXUAL REPRODUCTION.

The sexual organs of Marchantia are situated upon special receptacles—the male are shield-shaped, with a scalloped outline, the female radiating like bare umbrella ribs. The two sexes are situated upon different plants (dicœcious).

(1) **The Male Receptacle** consists of a stalk surmounted by a flat disc, it is a metamorphosed branch of the thallus. The upper side of the receptacle has the same structure as the dorsal surface of the thallus, and the under side has the same structure as the ventral surface, and bears rhizoids and scales. On the upper surface sunk in special cavities are the *antheridia*. In each cavity is one antheridium, besides some short unicellular *paraphyses*. The cavity closes above the antheridium into a narrow canal. The antheridium is a shortly-stalked oval body with a unilamellar chlorophyll-containing wall. It makes its appearance first of all as a papilliform swelling, this divides into two, the upper becomes the antheridium and the lower the stalk. The upper cell dividing successively by walls at right angles produces a closely aggregated tissue of small square cells; these are the mother cells of the

antherozoids (spermatozoids). The cells round themselves off and separate from one another. The antheridium tears at its apex, and the small round cells are evacuated. The wall of these small cells when brought in contact with water, swells and bursts, and the male reproductive organs are liberated into the water. They each have a thread-like body, and two long cilia. To the posterior end often clings a bladder (which probably has its origin in the central vacuole of the mother cell) which is lost during the swarming.

(2) **The Female Receptacle** forms a radially-spreading inflorescence, consisting as a rule of nine rays though more are occasionally present. Between these on the under side are the *archegonia*. Each row of archegonia is enclosed in a common veil-like covering, fringed at its edges and called the *perichætium*. The oldest archegonium lies nearest the edge and the younger progressively nearer the stalk. In a ripe archegonium the following parts can be distinguished :—

(1) A short stalk.
(2) A ventral portion.
(3) The neck.

An **Archegonium** arises in the following way :—

(1) A simple papillæ makes its appearance.
(2) This papillæ is cut off by a septum.
(3) A second septum appears—the lower cell

becomes the pedicel, and the upper the archegonium.

(4) The pedicel cell undergoes numerous transverse and longitudinal divisions, so that a multicellular stalk is produced.

(5) The mother cell of the archegonium produces three longitudinal walls, by which three outer cells are formed and one inner.

(6) The three outer walls divide up by longitudinal radial walls, so as to form six outer investing cells.

(7) The median cell divides by a transverse wall into an upper and a lower cell, the upper is called the *neck canal cell*, and the lower the *ventral cell.*

(8) Each of the six outer investing cells divides into two by a transverse wall, and so two tiers of cells are formed, the lower tier becomes the *ventral portion* and the upper the *neck.*

(9) The internal cell of the ventral portion—the ventral cell—increases considerably in size and is divided by a transverse septum into a large inferior cell, the *oosphere* or *ovum*, and a small upper cell—the *ventral canal cell.*

(10) Meanwhile the upper tier of cells elongates, and the neck canal cell divides into four, eight, or sixteen long narrow cells, these are the *canal cells of the neck.*

(11) Transverse and longitudinal walls are formed in the external cells of the ventral portion, and a wall consisting of one or two layers of cells is produced.

(12) The cells of the upper tier divide up and form the *neck*.

(13) The top cell of the canal chain of cells divides up by longitudinal division and forms five or six *stigmatic cells*.

The walls of the canal cell and the ventral canal cell become converted into mucilage, the swelling of which forces the stigmatic cells apart and the mucilage exudes through the opened neck.

Fertilization must take place under water. The antherozoids swim by means of their cilia, are attracted by the archegonia, get caught in the mucilage and wriggle themselves down the canal of the neck into the ovum. Their bladders and cilia get lost during the swarming in the mucilage. One unites with the nucleus of the ovum, and fertilization has taken place.

RESULTS OF FERTILIZATION.

The ventral portion from this time is called the *Calyptra*.

(1) The fertilized ovum secretes a cellulose wall and forms respectively the epibasal and hypobasal cells. The epibasal cell becomes the

sporogonium, or spore capsule, and the hypobasal cell the short *seta* or stalk.

(2) The first division is followed by two others at right angles to it and to each other, so that the embryo now consists of eight cells.

(3) Subsequent divisions take place more irregularly, and the seta and the sporogonium become differentiated.

a. The *Seta* is a short stalk consisting of a mass of squarish cells.

b. The *Sporogonium* exhibits three sets of tissue :—

i. *The Wall*, which consists of a single layer of flattened cells.

ii. *The Elaters*. Long cells, which taper at both ends and are thickened by from one to three spiral bands.

iii. *The Spore Mother Cells*, which are arranged in rows between the elaters.

The sporogonium is thus a shortly-stalked ball, enclosed in the female sexual organ; it is destined exclusively for the production of spores. It is not organically united with the previous generation, but is nourished by it.

(4) While this has been going on, the neck of the Archegonium first closes and then shrivels up and becomes brown, and the Calyptra increases in size to accommodate the large sporogonium.

(5) Each spore mother cell gives rise to four spores in the following way :—

i. The nucleus divides into two and each of these into two, so that four nuclei are formed, sometimes all in one plane and sometimes in two planes.

ii. Two cell walls are developed in such a way that each of the four cells thus produced has its own nucleus.

iii. The protoplasm collects round each nucleus, and the outer layer of each mass is converted into cellulose. The investing cell walls become disorganised, and the spores are free in the sporogonium.

(6) In the meantime, from the base of the archegonium is developed an investing coat called the *Perigynium*, which surrounds the archegonium as a sac.

(7) The Sporogonium is now ripe, the seta elongates rapidly, this ruptures the calyptra and the sporogonium protrudes. The calyptra surrounds the base of the seta as a cup-like membranous structure.

(8) The wall of the sporogonium ruptures irregularly, and the spores are liberated. The elaters, which are strongly hygroscopic, bend to and fro with the changes in the atmosphere, and so assist in the dissemination of the spores.

Spores. Each spore is yellow, and finely pitted. It has a thin exospore provided with excrescences, and an inner layer—endospore—of pure cellulose. Its cavity is filled with colcurless protoplasm, chlorophyll grains, starch and oil.

It germinates at once, and gives rise to the thalloid stem.

ALTERNATION OF GENERATIONS.

Spore produces Thalloid Stem } *Oophyte*
Thalloid Stem produces Sexual Organs } *Generation.*

Sexual Organs produce Sporogonium } *Sporophyte*
Sporogonium produces Spores. } *Generation.*

The Sporophyte is parasitic upon the Oophyte Generation.

Class.—MUSCINEÆ.

Sub-Class.—MUSCI.

Order.—Bryinæ.

Type.—A MOSS. FUNARIA HYGROMETRICA.

General Characters. A small leafy plant, bearing a stalked capsule, found abundantly in woods.

LIFE HISTORY FROM THE SPORE.

The spore is round, with an outer cuticularised wall (exospore) and an inner wall of pure cellulose (endospore). The cavity contains protoplasm and a nucleus.

The exospore bursts and the endospore protrudes, forming a *germ tube*. It grows rapidly as a filamentous structure and becomes septate. It branches freely and forms *ascending branches* which contain large chlorophyll grains. The *procumbent filaments* are obliquely septate, a septum is always found in front of a lateral branch. The part of the endospore which lies opposite the germinating filament develops into a rhizoid which *penetrates into the ground.* It branches freely, its septa are very oblique and its walls thick and brown. The whole of this tissue is called the *Protonema.*

Vegetative Reproduction of Protonema.

(1) Certain rhizoids swell at their apices and form multicellular tuberous structures. The cells fill with oil and *resting gemmæ* are formed. These last through the winter, germinate in the following spring and form a fresh crop of protonema.

(2) *Any single cell* of leaf or stem of the moss plant may grow out and form a protonema.

(3) The whole structure dies away in the autumn with the exception of the rhizoids, which germinate in the following spring, and form a new protonema.

DEVELOPMENT OF MOSS PLANTS.

Little swellings appear on the lateral branches of the protonema. Each grows rapidly by means of a three-sided apical cell and forms the moss plant bud. Each segment cut off by the apical cell bulges out and forms a leaf.

The **Leaves** are small, sessile, and broad at their insertion. Each lamina is only one cell in thickness. The midrib consists of a compact mass of elongated cells. Stomata are never found.

The **Stem** is roughly triangular, and shows an *epidermis* not well defined, an *outer cortex* of small thick-walled cells which passes over into an *inner* thin-walled *cortex*. The *central cylinder* consists of a mass of small, thin-walled cells, which corresponds to

the *phloem* of the higher plants and serves as a food-conducting tissue, and a solid cylinder of cells with thick walls, which corresponds to the *tracheides* of the higher plants and carries water. In the cortex are found *leaf trace bundles* with the same rudimentary structure.

The moss plants bear the sexual organs.

SEXUAL REPRODUCTION.

(OOPHYTE GENERATION.)

Funaria is dicœcious, *i.e.*, one plant bears entirely either male *or* female organs. Both sexes are *never* produced on the same plant.

1. Antheridia. These are the male organs, and they appear in great numbers at the apex of the stem, the surrounding leaves being specially modified to protect them. The protective leaves are small, closely packed, and are known as *Perichœtial* leaves.

A mature antheridium is a long, club-shaped sac, with a wall one cell in thickness which is green at first and later on red or yellow. The antherozoid mother cells fill up the sac. The cells near the top of the sac become turgescent, and the outer wall ruptures. The mother cells escape, but not before each one has produced an antherozoid. An antherozoid is a spiral nuclear body provided with two cilia. On the addition of water to the mother cells the antherozoids are liberated.

Among the antheridia are green, unbranched structures called *Paraphyses.* Each paraphysis is a

filament of cells, the terminal one of which grows large and fills with mucilage. This absorbs watery vapour and gives it up to the Antheridia which are thus well supplied with water.

2. The Archegonia. These are the female organs and like the Antheridia are produced at the apex of the stem and are surrounded by protective (*Perigonial*) leaves. The archegonia are *stalked* flask-shaped bodies with a thickened *ventral portion* and a very long *neck*. *The ovum*, *ventral canal cell*, and *neck canal cell* are similar to those developed in Liverworts, and fertilization is effected in the same way.

3. Results of Fertilization. (The development of a *Sporophyte Generation.*)

(1) The fertilized ovum secretes a cell wall and divides into two by a wall at right angles to the long axis of the archegonium.

(2) The lower cell grows rapidly and forms a penetrating organ which grows down and then turns up like a crotchet hook. This absorbs nourishment from the moss plant, but is not organically connected with it.

(3) The top cell forms a spindle-shaped body which consists of a very long stalk or *Seta*, and a capsule or *Theca* in which the Spores are developed. The capsule and stalk are together spoken of as the *Sporogonium.*

The archegonium keeps pace for some time steadily enlarging to accommodate the sporogonium, but

eventually it ruptures near its base. The upper portion is carried up on top of the Sporogonium and forms the so-called *Calyptra* or cap. The lower portion forms a sort of a saucer-like sheath at the base of the seta and is called the *Vaginula.*

The Theca (or Spore Capsule) is fusiform in shape and consists at first of a mass of undifferentiated tissue, the central portion of which persists and forms the *columella.* Surrounding the columella is the *spore sac,* and next to this a large air *cavity* traversed by cellular filaments of cells. The extreme outside consists of a *wall* a few cells in thickness, the external layer is considerably thickened.

(a) *Formation of spores.* Each spore mother cell gives birth to four spores formed tetrahedrally.

(b) *Dehiscence.* The Theca dehisces by detaching its upper portion in the form of a lid called the *Operculum.* Certain cells above the level of the columella become fibrously thickened, and form a complete ring. This is called the *Annulus,* and it is the annulus which contracts and casts off the operculum.

(c) *The Peristome.* Before the operculum is cast off—the peristome—a special arrangement to facilitate the dispersion of the spores is elaborated.

Directly above the air cavity and immediately within the epidermis a single continuous layer of cells becomes thickened. This layer extends all round the theca and reaches from the annulus to the

top of the theca. The outer tangential walls become strongly thickened and the inner ones in a less degree. The transverse walls are partially thickened. When the annulus and operculum are thrown off, all the remaining tissue, with the exception of the thickened walls, shrivel up, and the spores fill up the theca. The peristome thus consists of two concentric circles, the outer being termed teeth, and the inner cilia. The teeth and cilia are hygrospopic in a different degree.

ALTERNATION OF GENERATIONS.

Spore produces Protonema. Protonema produces Moss Plants. Moss Plants produce Sexual Organs.	*Oophyte Generation.*
Sexual Organs produce Sporogonium. Sporogonium produces Spores.	*Sporophyte Generation.*

The alternation of generations in the *Muscineæ* is the converse to that exhibited in the Vascular Cryptogams. The Sporophyte is parasitic upon the Oophyte Generation.

Class.—LYCOPODINÆ.

Order,—Selaginelleæ.

Type.—SELAGINELLA MARTENSII.

MORPHOLOGY.

Habit.—*Creeping* stems, *dichotomously* branched—branches all in *one plane*—bearing two kinds of leaves, large and small. These are ligulate. The *large ones* are inserted on the *ventral* surface, and the small ones on the *dorsal*. One large and one small leaf make a pair. The arrangement is decussate. Besides the leafy branches, leafless ones—*rhizophores*—are produced where the stem forks. These grow downwards, and produce at their apices tufts of true roots provided with caps.

Growth. Grows by means of a four-sided apical cell, which cuts off segments parallel to each of the three sides which are imbedded in the surrounding tissue.

ANATOMY.

Stem. *Epidermis.* Thickened *outer cortex*—thin *inner cortex*—no intercellular spaces—(interrupted by small leaf trace bundles) and the central cylinder consists of either one or three vascular bundles.

BUNDLE.

1. GENERAL CHARACTERS.

Centric, i.e., the tissues are arranged in concentric zones.

Closed, i.e., no generating tissue called cambium is present.

Cauline, i.e., each bundle is found to terminate in the stem, and does *not* enter a leaf.

2. TISSUES.

(a) *Wood or Xylem*, which shows two protoxylem groups, and two sets of elements. These are *tracheides* and *parenchyma*. Each tracheide consists of an elongated, thick-walled empty cell, whose great function is to carry *water*. The tracheides are marked by bordered pits. The parenchyma consists of smaller cells, retains its contents, and stores up starch.

(b) *Bast or Phloem*. This surrounds the wood, and consists also of two sets of elements. These are *Sieve Tubes* (or Bast Vessels) and *parenchyma*. The Sieve Tubes are elongated, contain protoplasm and various albuminoids, but no nucleus. They are characterised by perforations on their inclined and radial walls, through which the contents stream. Their great function is to *conduct* the albuminous food material. The Parenchyma is thin-walled, each cell is nucleated and *stores up* albuminous food material.

The Pericycle is one cell in thickness, forms a sheath round the phloem, and stores up starch.

The Endodermis, which in Ferns and the higher plants consists of a continuous ring of cells, is here represented by a large air-space, traversed by bridges of tissue called *Trabeculæ*.

Leaves. Small—sessile—thin.

Epidermis. Cuticularised, and contains chlorophyll.

Stomata. Middle of under surface.

Mesophyll. Not differentiated.

Bundle. One—same structure as stem bundle.

Root. General structure same as stem except that the skin being absorptive, is known as the *pilifery*, instead of epidermis. *Branching* mostly exogenous—segments cut off by the apical cell form the lateral roots.

Root Growth. An apical cell. Free upper surface cuts off the cap cells. The other segments cut off as in the stem.

REPRODUCTION.

The male and female reproductive organs are produced on fertile branches. The fertile leaves form a quadrangular spike, the leaves are uniform in size and usually somewhat of a different form from the barren ones.

The *Sporangia* are of a considerable size in proportion to the leaf, and are borne on short, thick stalks. Each fertile leaf bears a single sporangium, which always lies below the ligule, either on the leaf itself or on the stem. Each sporangium is a capsule.

Capsules containing four (2-8) large spores (female) are called *megasporangia* or *macrosporangia.*

Capsules containing an indefinite number of small spores (male) are called *microsporangia.* The microsporangia are borne on one side of the branch, and the megasporangia on the other side, or the microsporangia above and the megasporangia below.

DEVELOPMENT.

The early stages are the same in both cases.

I. Microsporangia.

(1) A group of superficial cells in the axil of the ligule becomes active, and gives rise to a small protuberance. By repeated division a mass of tissue is formed which differentiates into an outer layer and an internal group, one of which, the hypodermal cell in the axial row, becomes the *archesporium*, and the lower ones the stalk.

(2) The archesporium cuts off cells which go to form the *tapetum* on the free side, and the cells of the ground tissue form it towards the base.

(3) After the development of the tapetum, the archesporium divides up rapidly, and produces

a mass of *spore mother cells*. While this has been going on the outer wall divides up by tangential walls, and so the wall of the sporangium is now two cells in thickness.

(4) The mother cells round themselves off and become isolated from each other. Each mother cell divides up into four daughter cells, each of which is tetrahedrally shaped: they retain their relative position until mature. An immense number of these small spores is thus produced. The tapetum persists until the spores are ripe (while in ferns it is absorbed during the formation of the spores). The following changes, called *Germination*, now take place while the spores are still WITHIN THE SPORANGIUM:—

(a) At one end of the spore a small cell is cut off by a *very* firm wall. This cell has no function to perform, and is called the *Vegetative Cell*, and may be considered as a rudimentary prothallium.

(b) Successive division now takes place in the larger part of the spore—the whole of this tissue is regarded as the *Antheridium*, and the central tissue becomes the *Antherozoid* (*spermatozoid*) *Mother Cells*.

(c) Each mother cell contains a nucleus and protoplasm. The nucleus grows at the expense of the protoplasm, and forms a spiral

body, which is orginally curved round the central vacuole. In the meantime, the protoplasm which is left, becomes differentiated into two delicate fibrils, which attach themselves to the spiral nucleus at one end. The vacuole, not unfrequently, as it is surrounded by a delicate layer of protoplasm, remains attached to the posterior end of the *Antherozoid.*

(d) The sporangium bursts, and the spores fall to the ground. From the commencement of germination to the maturity of the antherozoids there is an interval of about three weeks.

II. Megasporangia.

Stages 1, 2, and 3 same as Microsporangia.

(4) One mother cell grows more strongly than the rest; it divides, and gives birth to four megaspores—again tetrahedrally shaped. The megaspore is surrounded by a cuticularised wall which is difficult to cut. All the other mother cells remain undivided—their ultimate fate is to be absorbed, though they exist in some species for a considerable time. *Germination* begins to take place while the megaspore is still IN THE SPORANGIUM.

(a) The protoplasm lying towards the corner divides up and forms a delicate plate-like cellular tissue, which afterwards produces

the *archegonia*, and is therefore the *true prothallium*. Usually at this period the megasporangium bursts, and the spores fall to the ground.

(b) A few weeks after dissemination, free cell formation begins in the remainder of the spore cavity, and the whole space is filled up by a large-celled tissue which is called *Endosperm*. The megaspores now contain both a prothallium and an endosperm.

DEVELOPMENT OF ARCHEGONIA.

The archegonia are produced from the prothallium thus :—

(1) A superficial cell divides parallel to the surface.

(2) The upper of the two cells divides into four cells by two walls at right angles to each other.

(3) Each of these divides into two by an oblique wall. In this way *the neck* is formed, consisting of four rows, each two cells in thickness.

(4) The lower of the first two cells sends out a narrow prolongation between the neck cells; this becomes the canal cell of the neck—this *neck canal cell* forces the neck cells apart.

(5) The lower swollen portion cuts off a small cell which is called the *ventral canal cell* and the inferior large one the *ovum* or *oosphere*.

(6) The two canal cells now become mucilaginous, and the archegonium is ready for fertilization.

All these changes have gone on *in* the spore, the early ones while the spore was in the sporangium, and the later ones after the dissemination of the spores. The outer cuticularised wall bursts soon after the archegonia begin to appear, the prothallium is liberated and slightly protrudes; the three convergent edges burst lengthwise and form a three-rayed fissure. At the apex the first archegonium is in process of development.

FERTILIZATION.

This must take place in water. The walls of the Antherozoid mother cells become disorganised, and the antherozoids are set free. They show active movement and swim away by means of their cilia. Their movement after liberation lasts from thirty to forty-five minutes. A drop of mucilage exudes from the archegonium – the antherozoids swim about aimlessly till they come within microscopic distance of an archegonium. They approach the opening, become entangled in the mucilage, and screw and wriggle down the canal until they reach the ovum. One antherozoid fuses with the nucleus of the ovum, and fertilization is effected.

Changes after Fertilization.

(1) The ovum secretes a cell wall.

(2) Division by a transverse wall takes place.

(3) One of these cells elongates, and forms the *suspensor*, which gives rise to a number of

divisions on the side nearest the embryo—this suspensor is wanting in all other Cryptogams, but universally present in Phanerogams, and through which *Selaginella* consequently approaches the flowering plants.

(4) This elongation causes the embryo to be forced into the tissue of the endosperm, where it undergoes further development. Two cells are formed by a transverse wall, these divide by a wall at right angles to the first. Two of these cells go to form the *foot*, which conveys nourishment from the prothallus to the growing stem and leaf. The root is formed some time after, from one of its inner segments. The foot is a characteristic of Cryptogams. One of the remaining cells of the original four goes to form the stem, and the other the leaf.

Class.—FILICINEÆ.

Order.—Filices (Ferns).

Type.—THE MALE FERN. ASPIDIUM FILIX-MAS.

MORPHOLOGY.

The underground stem or *rootstock* is fleshy, and covered with dead leaf bases. This stem differs from other stems only in degree. There are no *internodes*. The apex is always crowned with the leaves of the present year arranged on a more or less flattened axis; it takes two-and-a-half years for Aspidium leaves to unfold. The old portions of the rootstock die away. The young leaves are clothed with flat, brown, relatively large hairs called *Ramenta*. The function of this ramentaceous covering is threefold :—

1. It prevents too rapid transpiration.
2. It protects from sudden changes of temperature.
3. It protects from the attacks of parasites.

The Leaves are known as *Fronds*. They arise in *acropetal succession*, bear the *reproductive organs* on their under surfaces, and are characterised by *circinate vernation*.

Vernation means the folding of the individual leaves.

Circinate that they are rolled up from the apex downwards.

From the *bases* of the leaves arise *tufts of roots* and from the *back* of every twelfth or fifteenth leaf arises a *bud*. The stem is unbranched, any apparent branching will be found to be a plant arising from a bud.

ANATOMY.

1. The Stem.

In transverse section the following structure is presented .—

(a) Epidermis. This consists of small cells, the outer walls of which are strongly cuticularised.

(b) Thin-walled Cortex which is parenchymatous, and serves as a storing tissue.

(c) A band of Sclerenchyma, whose function is merely a mechanical one. This tissue exhibits the thin places called "pits."

(d) Vascular Bundles more or less regularly arranged in a ring. The ground tissue (parenchyma) separating the bundles receives the name of *Medullary Rays*.

(e) Pith. This is extensive.

Bundles.

i. Course. The *Cauline* bundles form a meshwork bearing a number of diamond-shaped openings called *Foliar Gaps*. Each gap marks the insertion of a leaf. From the margins of the

gap the bundles which enter the leaves arise. These are called *common* bundles. In the petioles (leaf stalks) the bundles run straight.

ii. Structure. The bundles are

Cauline, *i.e.*, they do *not* enter the leaves.
Centric, *i.e.*, the tissues form concentric zones.
Closed, *i.e.*, there is *no* generating tissue called Cambium present.

Each bundle is surrounded by a continuous sheath differentiated from the ground tissue called the *Endodermis*. This is only one cell thick; the cells are cuticularised on their radial walls, and store up starch.

Next to the Endodermis is found the *Pericycle*, which is usually many cells in thickness. It also serves to store up starch. In Phanerogams the Pericycle is seldom more than one cell thick.

Within the Pericycle is found the *Phloem* (Bast). The Phloem lying next to the Pericycle is called *Protophloem*, and consists of small parenchymatous cells. Lying within the Protophloem is found the *Metaphloem*, which consists of parenchyma and sieve-tubes; these last, as their name implies, are tube-like structures: the perforations or pores which characterise these elements are found on their radial walls. The companion cells of the angiosperms are not found here. The function of the Phloem Parenchyma is to store

up the albuminous food materials, and the function of the sieve-tubes is to conduct them.

Within the Phloem is the *Xylem* (Wood), which shows two *Protoxylem* groups. The *Metaxylem* meets in the middle. The protoxylem consists entirely of *Spiral Tracheides*; the metaxylem consists of *Parenchyma* and *Scalariform Tracheides*. The function of the Parenchyma is to store up *Carbohydrates* (Starch), and the function of the Tracheides is to carry *water*.

2. The Leaves.

As seen in section, beginning at the upper surface, present the following structure:—

(a) Epidermis. This consists of small cells, packed so that there are no spaces. The outer walls are cuticularised.

(b) Palisade Parenchyma, consisting of long narrow cells rich in chlorophyll grains.

(c) Spongy Parenchyma, consisting of rounded or irregularly-shaped cells. These cells are separated by large spaces.

(d) Lower Epidermis, which is interrupted by stomata. The stomata are confined to the middle part of the under surface.

Each *vein* is a vascular bundle, surrounded by colorless parenchyma. The bundle has a well-defined endodermis, and exhibits the same structure as the stem bundles.

3. The Root

Is protected by a *cap* many cells thick. Behind the cap is the root-hair region. As has been already stated, the roots arise from the leaf bases. In transverse section a young root presents the following structure :—

(a) Pilifery. This is one cell thick, and produces the root hairs. The root hairs are absorptive, their outer walls becoming mucilaginous they adhere closely to the particles of soil.

(b) Cortex. The outer part of this tissue is thin-walled and the inner thick-walled.

(c) The Endodermis is similar in most respects to the endodermis found in the stem, the only difference being that *one* endodermis surrounds the whole vascular cylinder in the root, while in the stem *every* bundle has its *own* endodermis.

(d) The Pericycle is as a rule double, and like the endodermis encloses the whole vascular cylinder.

(e) The Vascular Cylinder consists of two phloem groups opposite each other, and two xylem groups opposite each other and alternate with the phloem groups. There are thus four distinct groups of vascular tissue arranged thus :

Bast

Wood Wood

Bast

The elements and functions of the Bast and Wood are the same as those already described unde Stem Bundles.

ORIGIN OF LATERAL ROOTS.

One cell of the *Endodermis* outside each protoxylem group grows larger than its neighbours. It divides up and forms a little cone of tissue. This "cone" increases in length and makes its way through the tissue of the cortex by absorbing the cells which are in its way. When it reaches the pilifery this too is absorbed, and finally its tip appears outside the mother root. It, even in this young stage, is found to be protected by a cap. It always exhibits a structure identical with its parent, and is said to be *endogenous* in its origin, because it arises in the deeply-seated endodermis. Lateral roots of the higher plants arise in the pericycle. The innermost layer of the cortex sometimes keeps up with the growth while it is still within the parent root; this cortical layer is then described as the *Digestive Sac*, because it assimilates the tissues of the mother root and conveys the protoplasm so obtained to the growing lateral root. The Digestive Sac is itself absorbed just before the lateral root emerges. In the higher plants the endodermis forms the Digestive Sac.

APICAL GROWTH.

Roots, stems and leaves grow by means of one cell. This cell presents the appearance of a solid triangle,

and so is four-sided. It is best described as a *tetrahedral apical cell.* The three sides of the triangle are embedded in the surrounding tissue and the base forms the free upper surface.

In the case of stems, segments are cut off in regular alternation parallel to the three sides embedded in the tissue. These divide up before settling down permanently.

In the case of roots the division is the same, *and* the free upper surface cuts off segments which go to form the cap cells.

SPOROPHYTE OR ASEXUAL GENERATION.

The Reproductive Organs arise on the under surfaces of the leaves in groups called *sori.* Each sorus is covered with an epidermal outgrowth called the *Indusium*, which is shield-shaped. Each sorus consists of many *sporangia.* The placentæ arise as little swellings above the vascular bundles. Each sporangium arises from one superficial cell. When mature a sporangium consists of: —

1. A short stalk which is branched. The terminal cell of the branch is large, and filled with mucilage.
2. A globe-like head, consisting of
 a. An outer wall one cell thick.
 b. Two tapetal layers cut off from the archesporium.
 c. Sixteen spore mother cells.

The mother cells round themselves off, and each produces four spores tetrahedrally. The spores float about in the sporangium in the material formed by the disintegrated tapetal cells.

Dehiscence. One layer of the sporangium becomes fibrously thickened. This layer stands out as a ridge, and is called the *annulus*; the wall of the sporangium dries up, the annulus contracts and rupture takes place at the weakest part. In this way the spores are liberated.

OOPHYTE OR SEXUAL GENERATION.

Germination of a Spore. The exospore splits, and the endospore forms a germ-tube, into which passes the nucleus of the spore. This germ-tube produces a small, green, heart-shaped body, called the Prothallium, the growing point of which lies in the depression. Later on, a cushion of tissue is formed just behind the apex. The prothallium contains chlorophyll in abundance, and is attached to the substratum by numerous rhizoids, or root-hairs. It has thus an independent existence. On the under surface are produced the sexual organs. The male, called *antheridia*, appear among the root-hairs at the posterior end, *i.e*, on the unicellular portion of the prothallium. The female, called *archegonia*, appear on the thickened portion just behind the apex.

Antheridia. Each antheridium which projects beyond the surface as a dome-shaped structure,

arises from one cell of the prothallium. The wall is one cell thick, and encloses a few mother cells. Each mother cell produces one antherozoid thus :

1. The nucleus grows large and corkscrew-like, and is invested by a specialised part of the protoplasm (kinoplasm) which is very clear at the anterior end.
2. The cilia are produced from the peripheral protoplasm and become attached to the anterior end.
3. A vesicle remains attached to its posterior end, which probably has its origin in the central vacuole of the mother cell.

The dome-shaped end of the antheridium becomes disorganised, and so do the antherozoid mother cells, and the antherozoids swim out.

Archegonia. Each archegonium arises from a superficial cell, and projects considerably beyond the surface. It presents the appearance of a water-bottle, the swollen part of which is embedded in the tissue of the prothallium. The swollen part called the *ventral* portion encloses the *ovum*, which is also known as the *oosphere*. This ovum consists of a large nucleus surrounded by a mass of dense protoplasm. Above the ovum, approaching the neck of the bottle-shaped structure, is a small cell called the *ventral canal cell*. The *neck* portion consists of four rows of neck cells, which surround one long cell known as

the *canal cell.* The canal cell in *Aspidium* does not undergo any division, but it always contains four nuclei, arranged one underneath each other. When this stage is reached, the canal cell with its four nuclei, and the ventral canal cell with its single nucleus, become disorganised and form a mass of mucilaginous material which absorbs water with eagerness. This causes the *stigmatic cells*, *i.e.*, the uppermost four of the neck cells, to split apart and so the neck is opened. The archegonium is now ready or fertilization.

Fertilization, This must take place under water. The antherozoids are liberated at about the same time that the necks of the archegonia are opened, The antherozoids are chemically attracted by the malic acid contained in the mucilage, are caught in large numbers, and wriggle and screw down the neck. During this operation they lose their cilia and vesicles. The one that reaches the nucleus of the ovum first is absorbed, and *fertilization is effected.*

Fertilization may thus be defined as the quickening of the ovum by means of the nuclear body of an antherozoid.

RESULTS OF FERTILIZATION.

The protoplasm surrounding the nucleus convulsively contracts, and acquires a cell wall. The following changes are constant in *Aspidium* :—

1. The nucleus divides into two, and a cell wall is developed parallel to the long axis of

the archegonium, this is called the *Basal Wall.* This separates the shoot-forming from the root-forming portion of the embryo.

2. A wall is next formed at right angles to the first which is known as the *Transversal Wall.*

3. A *Median Wall* is developed,

The embryo now consists of eight cells called *octants.*

4. Each octant forms a wall parallel to the basal one. The cell thus produced becomes the growing apex of each octant.

The four cells *nearest* the growing point of the prothallium are known as the EPIBASAL half of the embryo, and the four cells *farthest* from the growing point are known as the HYPOBASAL half.

I. EPIBASAL HALF. *Upper octant* forms the *stem*—sister octant a few hairs. *Lower octant* with help of sister octant forms the first *leaf.*

II. HYPOBASAL HALF. *Upper octant* with its sister octant forms the *foot. Lower octant* forms the *root*—sister octant a few root hairs.

The Foot swells and absorbs nourishment from the prothallium.

The Root makes its way into the ground, growing away from the apex of the prothallium.

The Leaf (Cotyledon) curls round the stem apex.

The Stem makes its appearance last.

The Root soon dies away, and is replaced by fresh roots, which are developed from the bases of the leaves.

The Foot shrivels up.

The Cotyledon persists until six or eight new leaves are formed.

APOSPORY.

The Prothallium may be produced from the *rudiments of a Sporangium* or be a direct *outgrowth from the leaf.* (Normally it is produced by the germination of a spore.)

APOGAMY,

The Fern Plant may be produced on the prothallium by the *outgrowth of a few cells* and not be produced as the result of the fertilization of an archegonium.

INDICATIONS OF TRANSITION.

If the prothallia be grown in crowds they produce nothing but antheridia. In *Aspidium* this is to be regarded as a pathological phenomenon, but in the other Cryptogams, *e.g.*, Horsetails, it is regularly realised.

ALTERNATION OF GENERATIONS.

The Fern Plant produces the Sporangia
The Sporangia produce the Spores
The Spore produces the Prothallium.
} *Sporophyte Generation.*

The Prothallium produces the Sexual Organs The Sexual Organs produce the Embryo The Embryo produces the Fern Plant	*Oophyte Generation.*

Note that the alternation of generations in *Selaginella* and *Aspidium* is similar to each other, but directly opposite to that exhibited in *Marchantia* and *Funaria*.

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